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26. Occurrence of *Chelura terebrans*, a crustacean destructive to the timber of submarine structures on the coast of the United States. *Proc. U. S. Nat. Mus.*, II, pp. 232-235 (1880).
27. On some points in the structure of a species of the "Willemoesia group of Crustacea." *Ann. and Mag.*, V, v, p. 269 (1880).
28. Crustacea of Mexico and Central America. *Am. Jour. Sci.*, III, XIX, pp. 332, 333 (1880).
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29. [Review of Kingsley] On a collection of Crustacea from Virginia, North Carolina and Florida, with a revision of the genera of Crangonidæ and Palæmonidæ [supra 5]. *Ann. Jour. Sci.*, III, XIX, pp. 423-424 (1880).
30. [Notice of Huxley's] The Crayfish; an introduction to the study of Zoology. *Am. Journ.*, III, XIX, p. 424 (1880).
31. Notes on Crustacea collected by Dr. G. M. Dawson at Vancouver and the Queen Charlotte islands. Report of progress of the Geol. Survey of Canada, 1878-79, pp. 206 B-218 B (1880).
32. On the species of Pinnixa inhabiting the New England coast, with remarks on their early stages. *Trans. Conn. Acad.*, IV, pp. 247-253 (1880).
33. Occasional occurrence of tropical and subtropical species of Decapod Crustacea on the coast of New England. *Trans. Conn. Acad.*, IV, pp. 254-257 (1880).
34. On the Amphipodous genera, Cerapus, Unicola and Lepidactylis, described by Thomas Say. *Trans. Conn. Acad.*, IV, pp. 268-284, pl. 11a (1880).

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ABORIGINAL STONE-DRILLING.

BY CHARLES RAU.

ABOUT twelve years ago, I published an account of my experiments in drilling in stone without the aid of metallic tools,¹ and, though during the interval my attention was constantly fixed upon archæological matters, I had, on the whole, no occasion for changing the opinions then expressed.

In the meantime, however, similar experiments, made by European archæologists, were commented on by Mr. John Evans, who, after a due consideration of the subject of stone-drilling, gives the following summary of methods:

"On the whole, we may conclude that the holes were bored in various manners, of which the principal were—

1. By chiseling, or picking with a sharp stone.
2. By grinding with a solid grinder, probably of wood.

¹ Drilling in Stone without Metal; Smithsonian Report for 1868, p. 392-400.

3. By grinding with a tubular grinder, probably of ox-horn.
4. By drilling with a stone drill.
5. By drilling with a metallic drill.

"Holes produced by any of these means could, of course, receive their final polish by grinding."¹

It appears doubtful to me whether in North America (north of Mexico) metallic tools for drilling stone were used, considering that the only metal which could have been employed for such purposes was hammered native copper—a substance too soft to be applied to any kind of hard stone without the aid of a very efficient triturated grinding material. Nor do I believe that the former inhabitants had sufficient skill in working copper to fashion it into a tubular tool suitable for stone-drilling; and to my knowledge no such object has ever been discovered in the United States. Soft stone, moreover, could be bored with greater facility by means of properly-shaped flint implements, as will be exemplified in this article. Even bronze, I think, would be found less serviceable than flint for drilling stone of inferior hardness.²

Dr. Ferdinand Keller, of Zürich, the meritorious investigator of Swiss lake-habitations, has made quite interesting experiments in drilling stone and other substances employed by the lake-dwellers. He operated on stone with tubular bones of goats and sheep, and with hollow cylinders of stag-horn and yew-wood, these drills being inserted into spindles slightly pressed at the upper end, and set in motion by means of a bow. This apparatus corresponded in general principle to that figured by me on page 399 of the Smithsonian Report for 1868. Water and quartz sand, of course, were necessary agents in the operation. Dr. Keller expresses himself quite satisfied with his success; for there appeared the round, smooth hole, with the characteristic parallel striæ and the core at its bottom, which is always seen in unfinished antique specimens drilled with a hollow tool. The work, however, progressed very slowly, and the operator adds to this statement the observation that no prepared hollow bone, which might have served as a drill, has thus far been discovered in the lacustrine deposits of Switzerland. After these experiments it occurred to him to employ a hollow cylinder made of ox-horn,

¹ Evans: *The Ancient Stone Implements, Weapons and Ornaments of Great Britain*; London, 1872, p. 48.

² For carving on hard stone, such as granite, bronze tools have been found to be almost useless. A trial of this kind is described in my Smithsonian publication entitled "*The Palenque Tablet in the United States National Museum*," p. 37, note.

and he obtained now more favorable results, owing to the yielding substance of the horn, in which the sand became imbedded and acted like a file. "The objection," he says, "that no drills made of this material have been discovered, is rendered invalid by the nature of the horns of bovines, which are totally dissolved in water in a comparatively short time."¹

Methods like those employed by Dr. Keller, may have been practiced by the aborigines of this country; yet among the hundreds of bone and horn implements which have passed through my hands during my connection with the United States National Museum, not one exhibited the character of a hollow drill, and I am not aware that any of the collections of this country contains such a tool. But I must not omit to state what I learned in 1875 from a Warm Spring Indian belonging to a delegation which had come to Washington for the purpose of transacting business with the Government. These Indians were well supplied with pipes, mostly made of alabaster, and shaped like the ordinary catlinite pipes. With some difficulty I obtained from one of them the information that they drill the cavities of their pipes with bone tools, and, in order to strengthen his assertion, he led me to a case in the Museum in which objects of bone were exhibited. The cavities of their pipes, some of which were purchased from them, appear to have been produced by solid rather than hollow drills. According to Catlin, the pipes made of the material now named after him, are (or were) drilled by means of a wooden stick, in conjunction with sand and water.

In my account of drilling, referred to in the beginning of this article, I should have stated with greater emphasis that, in illustrating the possibility of perforating very hard stone by employing a revolving stick and sand and water, I was far from underrating the efficiency of a flint tool for drilling stone of less obdurate character. In operating with a well-pointed flint arrow-head, firmly set in the cleft end of a short stick, on a fragment of a pierced tablet of tolerably hard slate, I produced in about half an hour a small perforation in no way distinguishable from one made by an aboriginal worker in stone. The perforations in these tablets are either conical or bi-conical. By drilling from both sides of the fragment I made one of bi-conical form; if I had continued

¹ Keller: *Durchbohrung der Steinbeile, Hirschhornwerkzeuge und anderer Geräte aus den Pfahlbauten*, in: *Anzeiger für Schweizerische Alterthumskunde*; Zürich, Juni, 1870, S. 139-144.

to drill from one side only, the bore would have assumed a conical shape. I simply turned the improvised tool with the hand like a gimlet, exerting a moderate pressure, and wetting the cavity from time to time with water. During the operation very diminutive particles of the drilling tool came off with a slight crack, and the flint showed afterward scarcely any wear. This fact is worth noting, as it accounts for the fresh appearance of many flint tools which undoubtedly have served for drilling purposes.

Any one who has handled a large number of North American flint implements must be aware that there are some which approach in outline more or less the arrow-head shape, but exhibit a rounded edge instead of a point. They might often be taken for cutters; yet many of them, I am now inclined to believe, served as tools for boring stone of inferior hardness, the curved extremity forming, of course, the penetrating part of the drill. My view is based upon the fact that an implement of this kind actually has been found in the unfinished bore of an aboriginal stone object, now in possession of Mr. James Wood, of Mount Kisco, Westchester County, New York. Last year that gentleman, who is President of the Westchester County Historical Society, was kind enough to send the partly-drilled specimen, together with the drill, for examination to the Smithsonian Institution, where I caused drawings of both to be made. The objects were found at Croton Point, on the Hudson, in Westchester County, by Mr. Wood's cousin, a lad about thirteen years of age, whose veracity cannot be doubted, and who is not at all given to collecting aboriginal relics, of which, indeed, he has no knowledge. The genuineness of the discovery is beyond any suspicion.

Figure 1 shows the character of the drilled object, which is a rather rude exemplification of a type not unfrequent in the United States, and represented by a number of specimens in the archaeological collection of the National Museum, where I have classed them for the present with the drilled ceremonial weapons, sometimes very inappropriately called "banner-stones."¹

The specimen in question consists of chloritic potstone, a very soft material, which could easily be fashioned and drilled. The

¹A specimen not unlike the original of Figure 1, though larger and of a more regular shape, was found in the town of Monkton, Vermont. It is figured and described in "Proceedings of the American Association for the Advancement of Science" (Twenty-eighth meeting, August, 1879); Salem, 1880, p. 526, etc.

bore is an inch and a half deep and nine-sixteenths of an inch in diameter at the orifice. It is straight and smooth, but shows parallel furrows or striæ impressed by the corners and slight lateral projections of the drill. The latter, represented by Figure 2, consists of black hornstone and is very carefully chipped. It is an entirely uninjured specimen. When Mr. Wood's young relation found the potstone implement, its bore was filled with earth, the removal of which brought to light the flint drill. It stuck in the

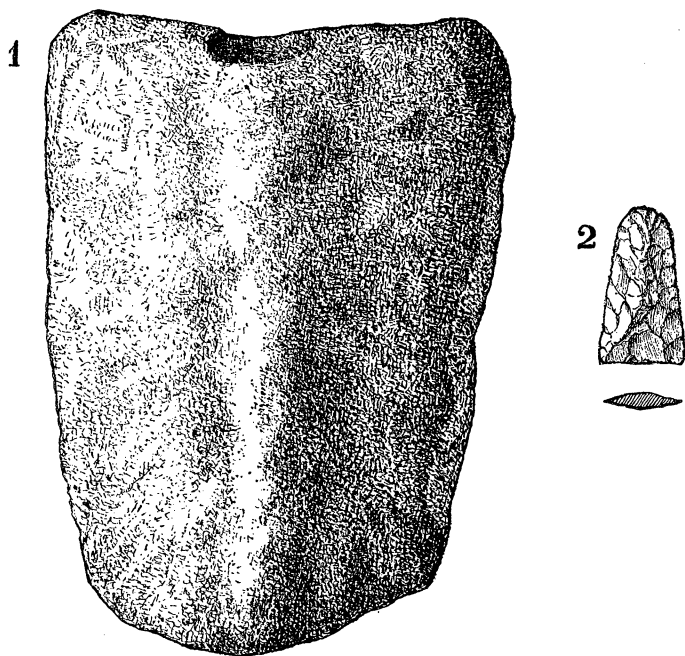
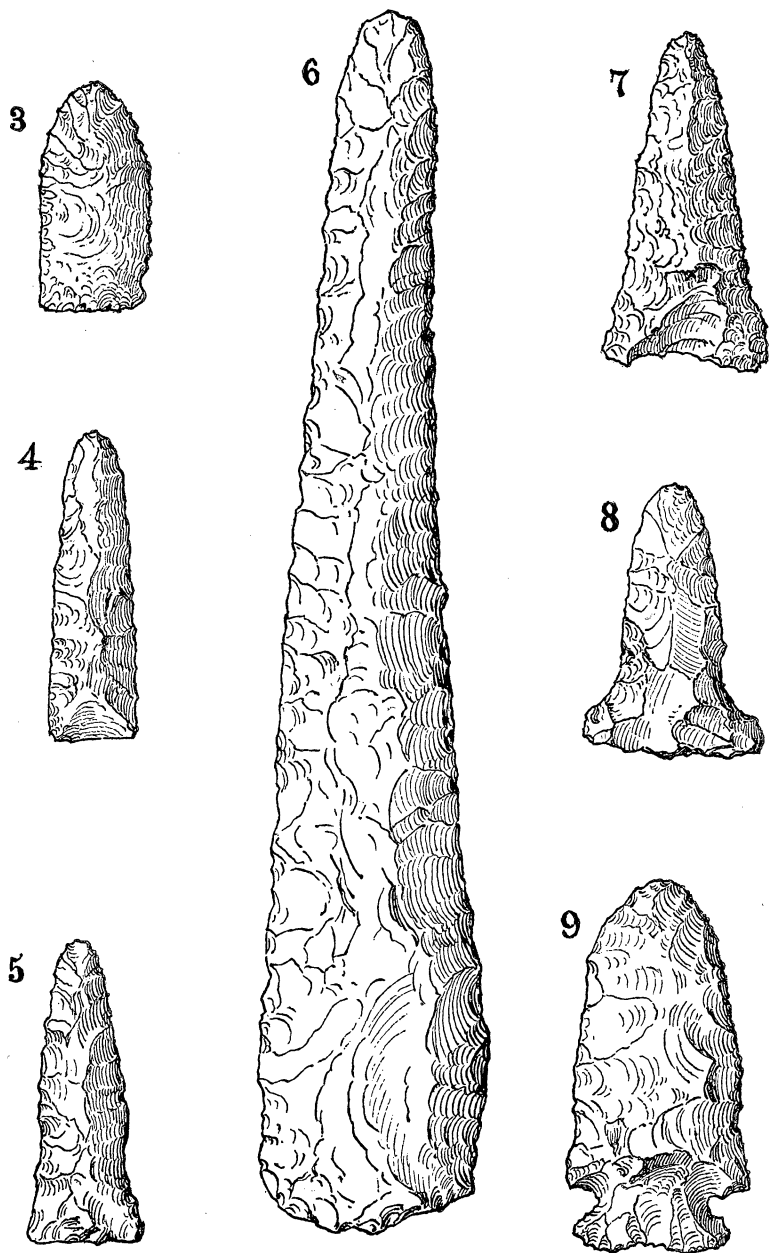


FIG. 1.—Stone object with unfinished bore, and (2) the drill used in the operation. Westchester County, New York (natural size).

lowest part of the bore, which exhibits here a shape corresponding exactly to the somewhat tapering form of the tool. No trace of a handle, without which the drilling could not have been performed, was found. Its material—doubtless wood—had totally disappeared.

It rarely happens that a discovery of such demonstrative character is made, and I therefore concluded to publish the present account, which, no doubt, will be of interest to the many who care for the details of North American archæology.

In Figures 3-9 I present delineations of some of the stone im-



FIGS. 3-9.—Stone drills in the U. S. National Museum (natural size).

plements in the National Museum, which resemble more or less

Mr. Wood's specimen, and to which I ascribe the character of drills.¹

Figure 3.—Original made of light-brown stone of chalcedonic appearance. Colorado. (Museum No. 9208.)

Figure 4.—Yellowish flint. Ohio. (Museum No. 16,484.)

Figure 5.—Gray jasper. New York. (Mus. No. 6180.)

Figure 6.—Cast of a large implement of brownish hornstone. The original is in possession of Mr. L. Leppelman, of Fremont, Ohio. (Museum No. 35,624.)

Figure 7.—Yellowish-brown jasper. Connecticut. (Museum No. 6084.)

Figure 8.—Dark-gray hornstone. Ohio. (Museum No. 16,484.)

Figure 9.—Light-reddish jasper. West Virginia. (Museum No. 13,376.)

Having properly hafted the original of Figure 8, I operated with it on a piece of an aboriginal potstone vessel, three-fourths of an inch in thickness, which I perforated in about twelve minutes, the result being a bore not quite as regular as that exhibited in Mr. Wood's specimen, but otherwise resembling it in all essential points. The manipulation was the same as in the previously-described experiment by which I obtained a small bi-conical perforation.

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ON THE EFFECT OF IMPACTS AND STRAINS ON THE FEET OF MAMMALIA.²

BY E. D. COPE.

THE principal specializations in the structure of the feet of the Mammalia may be summarized as follows:

I. The reduction of the number of the toes to one in the *Perisodactyla* (horses, etc.), and two in the *Artiodactyla* (cloven feet).

II. The second hinge-joint in the tarsus of the *Artiodactyla*.

¹ The specimen from the Yorkshire Wolds, represented by Figure 231 on page 291 of Mr. Evans's work (Ancient Stone Implements, etc.) appears to belong to the same class of tools.

² Read before the National Academy of Sciences, April, 1881. Abstract. Some of the points of this paper have already been discussed in the *NATURALIST* (April), but the present abstract contains additional matter.